2006

Ground Vibrations Arising from Using Two Types of Explosives - A Comparative Study

S. M. Hossaini
University of Tehran

Gour Sen
University of Wollongong, gour@uow.edu.au

GROUND VIBRATIONS ARISING FROM USING TWO TYPES OF EXPLOSIVES - A COMPARATIVE STUDY

S.M.F. Hossaini[1] and G.C. Sen[2]

ABSTRACT: Results of an investigation into ground vibrations carried out in an open pit coal mine in New South Wales has been analysed. As this mine is located in a sensitive area in regard to potential damage from ground vibrations, severe restrictions were imposed on the blasting operations. In this study 44 sets of recorded experimental blast data have been analysed. Two valuable equations have evolved from the data when two types of explosives were used. A comparison between the effects of two explosive types, namely ANFO and slurry, on ground vibration is presented. It has been shown that the intensity of ground vibration is greater for slurry in short distances but becomes same in a specific longer distance. It was also found that in long distances the intensity of vibration is greater using ANFO than slurry.

Keywords: Blasting, ground vibration, coal mine, particle velocity, explosive type.

INTRODUCTION

The understanding of blast induced ground vibrations is of prime importance in controlling environmental problems. The explosive type is one of the key factors in determining the intensity of ground vibration. The quantification of the effect of this parameter on vibration has been discussed in detail elsewhere (Hossaini and Sen, 2004).

Cumnock South Open Cut Coal Mine is located approximately 35 km north of the town of Singleton in the Hunter Valley Coalfield in New South Wales, Australia (Figure 1). The mine site is adjacent to the Howick Open Cut Coal Mine, bounded by the New England Highway to the North, the Pacific Power Liddell to Tomago 330 kV transmission line to the South, the Coal and Allied overland conveyor to the East, and Pikes Gully Road to the West.

Due to the mine's close proximity to the Pacific power transmission lines and a number of road bridges (Figure 2), it was of utmost importance that the blast vibration level resulting from blasting be maintained at a level acceptable to the limitations imposed.

The maximum allowable peak particle velocity, which is defined as the vector sum of the three orthogonal velocity components (Konya, 1990), imposed at Cumnock South mine was 25 mm/s for the pikes Gully Bridge, C&A Bridge, any steel transmission towers of the 330 kV transmission line, and 50mm/s for the wooden transmission towers (Walker, 1996).

Experimental blasts using two types of explosive, namely ANFO and Slurry, were monitored in order to investigate and to implement the most reliable blasting method, which would not produce any environmental problems.

In this investigation, a series of monitored experimental data was analysed. The best fitting equation for vibration prediction was established for each explosive type, through which the maximum instantaneous charge can be calculated with very high levels of confidence. A comparison of the performance of these two types of explosives from the vibration point of view was also conducted.

[1] *Faculty of Mining Engineering, University of Tehran*
[2] *Faculty of Engineering, University of Wollongong*

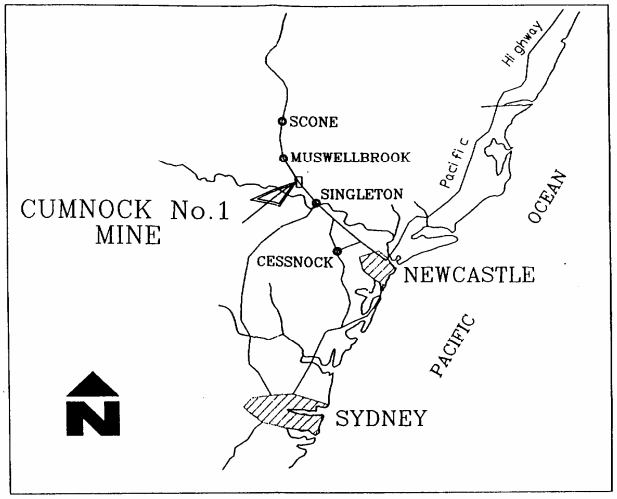

Fig. 1 - Location of Cumnock South Coal Mine in New South Wales.

GENERAL MINE DESCRIPTION

Cumnock coal is centred in the upper Hunter coalfield and forms part of the larger Permian aged coalfield known as the Sydney Basin. The Sydney Basin comprises sedimentary rocks such as conglomerate, sandstone and shale inter-bedded with many coal seams. Several clay stones of volcanic origin occur within the sequence and, due to their consistency, are used as major stratigraphic horizons. The coal resource is composed of nine seams that dip uniformly at approximately 4° to the South East. The mining activity commenced near the sub crop in the West and moved progressively down dip to the South East in 50 m wide strips (Robinson, Hagan and Tucker, 1995). The mine produced approximately 1.1 million tonnes per annum of coal and moved about 7 million cubic metres of overburden a year through a truck and shovel (hydraulic excavator) operation.

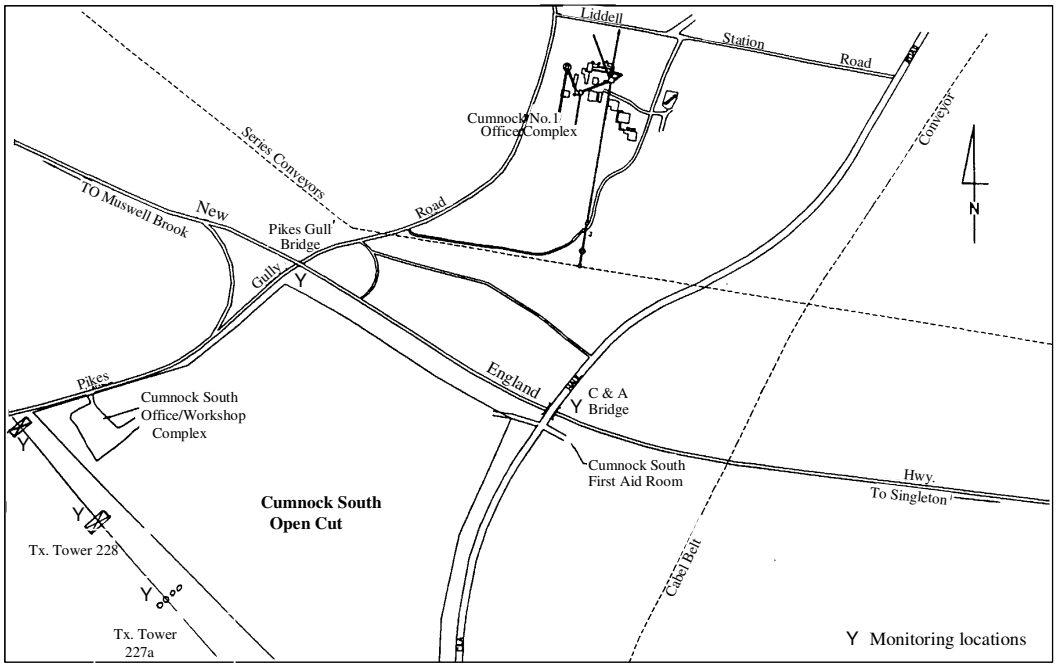

Fig. 2 - Monitoring locations

The blasting operation was conducted in the overburden. The overburden and inter-burden consisted mostly of siltstone and medium to thickly bedded sandstone. This stratification is free of significant joints or bedding planes and medium in strength. The average un-confined compressive strength was around 45 MPa.

As Cumnock South Open Cut Coal Mine is located in an area with many potential complaints about damage due to ground vibration, strict restrictions were imposed on the blasting operation. To implement a reliable shock reduction method, experimental blasts had been carried out in order to minimize the environmental problems (Hossaini and Sen, 2006).

The outline of drilling and blasting design at Cumnock South mine was as follows:

The bench heights were 10 m, 20 m or 28 m where in some cases two passes were required in order not to exceed the vibration limitation. The hole diameter used was 130 mm for the holes drilled for creating rock buffer and 187 mm for normal blasts. The initiation sequence was such that it progressed away from the sensitive area.

Blast vibrations were monitored using three Blastronic's Micro monitors at 5 locations shown in Figure 2. The monitoring points were positioned at sufficient distance from the structures to avoid undue vibration influence from the structures.

Cumnock South Cut operation was suspended in the late 90's. The data processed in this investigation relates to that era and not to the current project.

PEAK PARTICLE VELOCITY ANALYSIS

Data from 21 shots using ANFO (Table 1) and 23 shots using slurry explosive (Table 2) have been analyzed. When slurry was used, the explosive weight was converted into its ANFO equivalent, appearing in column 4 of Table 2 as (Maximum Instantaneous Charge) MICe (where subscript "e" stands for equivalent). As seen from Tables 1 and 2 the peak particle velocity (ppv) of ground vibration decreased rapidly as distance from the blast center to the survey station increased. The ppv decreased from an average of 37.9 mm/s at 42 m to 0.49 mm/s at 873 m for ANFO and from 32.07 mm/s at 93 m to 2.72 mm/s at 851 m for slurry.

Because the type of ground was assumed to be uniform in this study, it is reasonable to expect that any alteration in the ground vibration would be due to different explosive types as the only variable in this study.

The following scaled distance empirical equation originally proposed by US Bureau of Mines (Dowding, 1996) has been used for prediction of peak particle velocity:

$$v = k[\frac{D}{\sqrt{Q}}]^{a} \qquad (1)$$

Where v is peak particle velocity (mm/s), D is distance (m), Q is the maximum instantaneous amount of explosive charge (kg), $D/\sqrt{Q}$ is scaled distance (m/kg ^0.5) and k and a are normally called site specific parameters.

Applying non-linear regression, to both groups of the data, the best values of parameters k and a are found for Equation (1), in each case, with excellent levels of correlation. The analysis was carried out by Microsoft Excel for XP Windows.

In the following sub-sections, the criterion is assessed against both groups of the data and the results are discussed individually for each case.

Table 1 - Ground vibration measurements in standard blasts using ANFO

Event No	Distance (m)	MIC(Q) (Kg)	PPV (mm/s)	Scaled Distance
1	747.00	218.90	1.90	50.49
2	733.00	280.31	1.50	43.78
3	700.00	228.80	1.60	46.28
4	873.00	40.00	0.49	138.03
5	196.00	241.21	26.40	12.62
6	207.00	233.17	19.72	13.56
7	629.00	74.33	0.80	72.96
8	640.00	218.90	1.80	43.26
9	660.00	280.31	3.10	39.42
10	620.00	228.80	2.30	40.99
11	42.00	30.00	39.09	7.67
12	70.00	80.00	48.66	7.83
13	81.00	110.00	46.08	7.72
14	153.00	271.61	39.90	9.28
15	691.00	241.21	2.93	44.49
16	42.00	25.00	36.85	8.40
17	670.00	233.17	3.74	43.88
18	66.00	75.35	27.60	7.60
19	216.00	224.65	13.00	14.41
20	238.00	272.87	13.50	14.41
21	225.00	146.94	10.80	18.56

Table 2 - Ground vibration measurements in standard blasts using slurry

Event No	Distance (m)	MIC(Q) (Kg)	MICe (kg)	PPV (mm/s)	Scaled Distance
1	437.00	537.19	639.25	12.70	18.85
2	355.00	463.68	551.78	9.70	16.49
3	547.00	209.16	248.90	2.90	37.82
4	820.00	44.76	53.27	0.60	122.56
5	517.00	360.74	429.28	4.00	27.22
6	666.00	247.17	294.14	1.30	42.36
7	247.00	338.39	402.68	26.00	13.43
8	198.00	300.34	357.41	35.30	11.43
9	403.00	655.36	779.88	9.50	15.74
10	703.00	94.59	112.56	0.90	72.28
11	562.00	247.17	294.14	1.82	35.75
12	851.00	395.48	470.62	2.72	42.79
13	485.00	295.34	351.45	3.89	28.22
14	378.00	661.74	787.48	12.00	14.69
15	255.00	303.45	361.11	36.20	14.64
16	515.00	209.16	248.90	2.70	35.61
17	554.00	44.76	53.27	1.10	82.80
18	288.00	360.74	429.28	21.60	15.16
19	651.00	247.17	294.14	1.30	41.41
20	580.00	94.59	112.56	1.10	59.64
21	120.00	182.91	217.66	44.40	8.87
22	93.00	63.42	75.47	32.07	11.68
23	259.00	376.96	448.58	13.40	13.34

Vibration due to ANFO

Equation (1), was applied to 21 pairs of the data relating to the shots where ANFO was used. The best fit structure of the equation has been established between peak particle velocities and scaled distances with best possible values of coefficients of correlation (R) as follows.

$$v = 1269.9[\frac{D}{\sqrt{Q}}]^{-1.6628} \qquad (R=0.9924) \qquad (2)$$

Figure 3 represents the established equation along with the data.

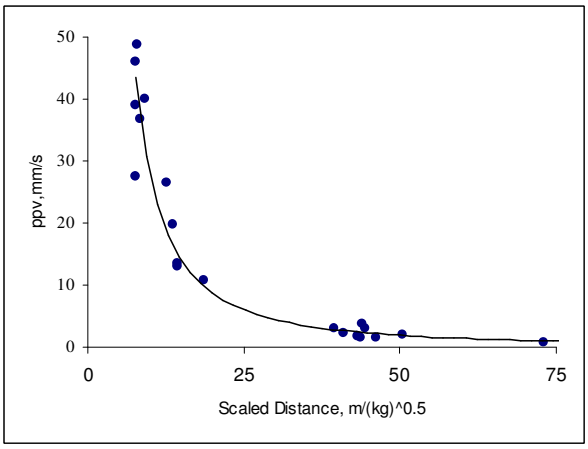

Fig. 3 - PPV versus scaled distance for blasts using ANFO

Vibration due to Slurry

Equation (1) was applied to 23 sets of the data relating to the shots where slurry explosive was used. Non-linear regression was carried out the same way as for ANFO. The following best fit forms of the equations has been established between peak particle velocities and scaled distances:

$$v = 2239.3[\frac{D}{\sqrt{Q}}]^{-1.838} \qquad (R=0.959) \qquad (3)$$

Figure 4 shows the established equation along with the data.

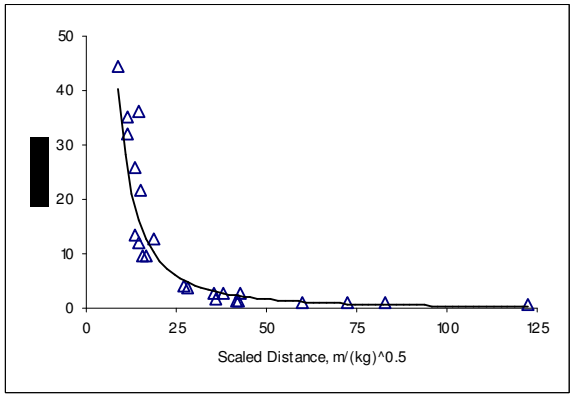

Fig. 4 - PPV versus scaled distance for blasts using slurry explosive

Attenuation of vibration

Attenuation trend of the peak particle velocities are presented in Figures 5 and 6 for the two types of explosives. Two best fitting equations describing the attenuation due to distance have been established and these are as follows:

For ANFO; $v = 51.538e^{-0.0049D}$ (R=0.962) (4)

For Slurry; $v = 86.119e^{-0.006D}$ (R=0.914) (5)

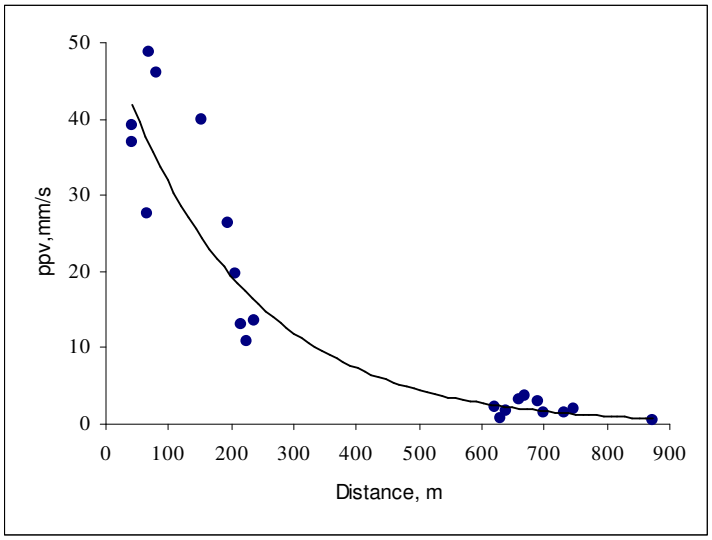

Fig. 5 - Attenuation trend of vibration for ANFO

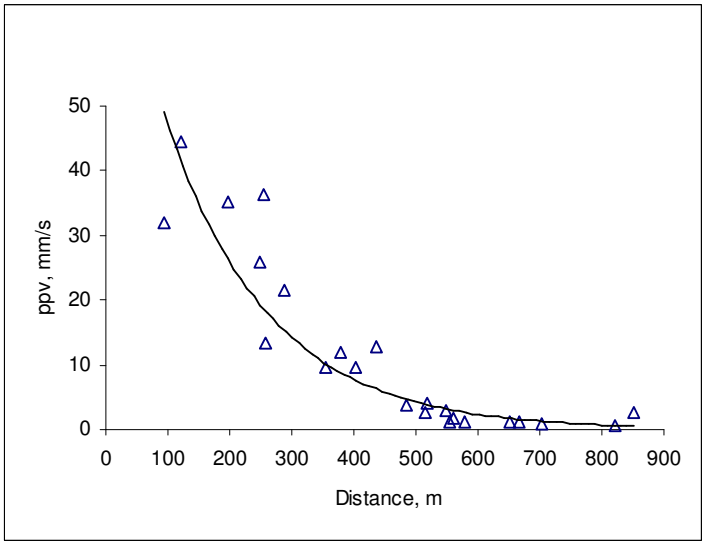

Fig. 6 - Attenuation trend of vibration for Slurry

COMPARISON OF GROUND VIBRATIONS VALUES

Figure 7 compares the magnitudes of ground vibrations for slurry and ANFO. In Figure 8 the rates of vibrations for these two types of explosives are plotted against distances. The values of ppv shown in this figure have been back calculated from equations 4 and 5 which were obtained for attenuations of vibrations as shown in Figures 5 and 6.

As seen in Figure 8, the intensity of vibration is much greater for slurry explosive. As the monitoring distance increases, both types of explosives (viz. ANFO and slurry) become similar and are virtually the same at long distances. In this study this phenomenon was evident at around 460 meters. This is because with the increase in distance the intensity of vibration is attenuated and dies down in far places. When very long distances are concerned, regardless of the type of explosive the ground vibration becomes weaker and weaker, and is finally untraceable.

An interesting point has emerged: in distances over 500 meters the intensity of vibration due to ANFO is greater than that of slurry. This can be interpreted as the effect of frequency. The waves with lower frequencies normally last longer and are more effective over long distances. Since the monitoring of vibration eaves did not record the frequencies in that period this hypothesis cannot be substantiated with any degree of certainty. However, it is likely that the waves produced by ANFO are mostly of lower frequencies than those produced by slurry. This can be considered as the reason for the higher ratio of ANFO to slurry proportion of vibration intensity in long distances.

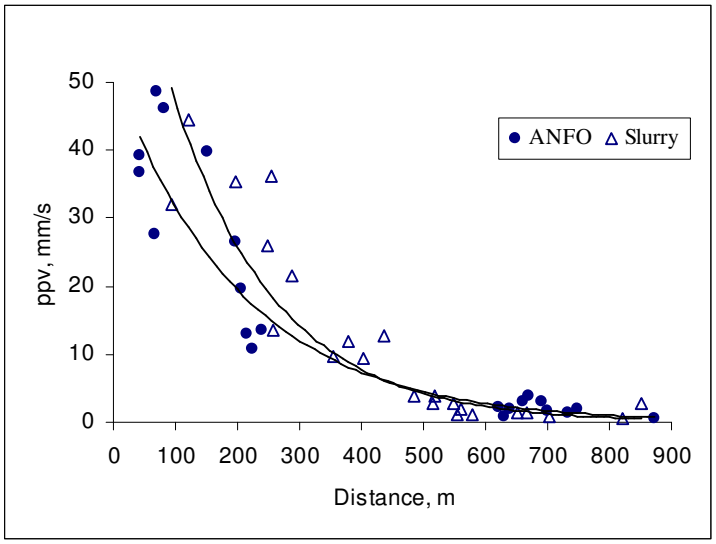

Fig. 7- Comparison of vibration intensity for ANFO and Slurry

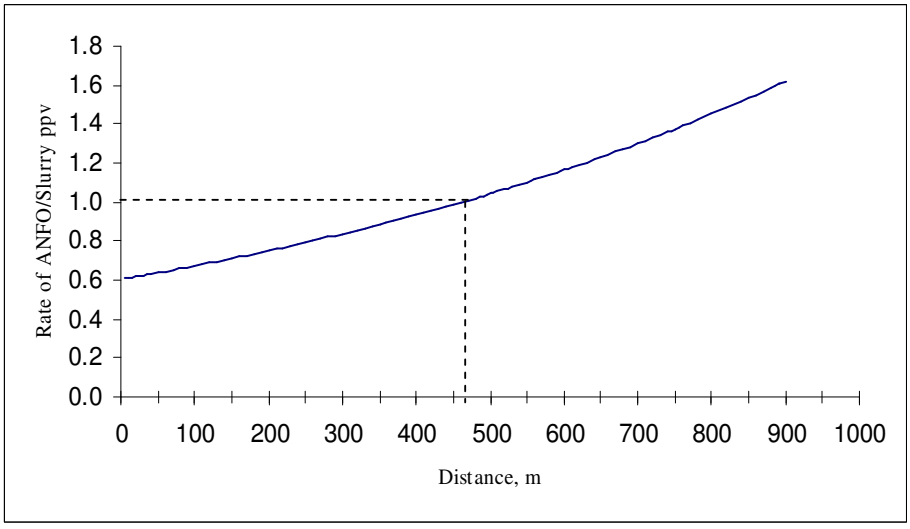

Fig. 8 - Rate of vibrations of ANFO to Slurry for various distances

CONCLUSIONS

The results of this investigation can be summarised as follows:

- The explosive type may significantly affect the intensity of ground vibration.
- In short distances, the intensity of vibration produced by slurry is much greater than that produced by ANFO.
- As the distance increases, the intensity of vibration grows closer for both types of explosives.
- At a specific distance both explosives produced similar vibration values.
- Beyond a specific distance the vibration becomes higher for ANFO than for slurry.
- The role of frequency is likely to effect the variation of vibration intensity at long distances.

ACKNOWLEDGMENTS

The first author wishes to acknowledge both the University of Tehran, Iran, and the University of Wollongong, Australia, for the opportunity and facilities they provided him during his sabbatical leave, without which this investigation would not have been possible. The second author gratefully acknowledges the constructive criticism made by G Robinson (Xstrata Coal Australia Pty Limited) in the preparation of this paper.

REFERENCES

Dowding, C H, 1996. Construction vibration. Prentice Hall Inc., Englewood Cliffs, NJ. USA, 604p.

Hossaini, S M F and Sen, G C, 2004. Effect of explosive type on particle velocity criteria in ground vibration, The Journal of Explosive Engineering, USA, Vol. 21, No. 4, July/August, pp. 34-39.

Hossaini, S M F and Sen, G C, 2006(in press). A study of the influence of different blasting modes and explosive types on ground vibrations, Iranian Journal of Science and Technology, Shiraz, No. 29B3.

Konya, C J and Walter, E J, 1990. Surface blasting design. Prentice-Hall, USA, 303p

Robinson, G J, Hagan, T N and Tucker, A J, 1995. Mine owner and explosive supplier-partners in controlling the environmental effect of blasting in proceedings of the Australian Institute of Mining and Metallurgy Annual Conference, 23-25 March, Newcastle, pp. 263-269.

Walker, G, 1996. An investigation into the effectiveness of buffer blast in limiting blast vibrations at Cumnock South Open Cut Coal Mine, BE thesis (unpublished), University of New South Wales, Australia.

MONOGRAPH SERIES

1	• Detrital Heavy Minerals in Natural Accumulates	*George Baker*	*1962*
2.	• Research in Chemical and Extraction Metallurgy	*Ed: J T Woodcock, A E Jenkins and G M Willis*	*1967*
3.	• Broken Hill Mines - 1968	*Ed: M Kadmanovich and J T Woodcock*	*1968*
4.	• Economic Geology of New Zealand	*Ed: G J Williams*	*1974*
5.	• Economic Geology of Australia and Papua New Guinea - 1 Metals	*Ed: C L Knight*	*1975*
6	• Economic Geology of Australia and Papua New Guinea - 2 Coal	*Ed: D M Traves and D King*	*1975*
7.	• Economic Geology of Australia and Papua New Guinea - 3 Petroleum	*Ed: R B Leslie H J Evans and C L Knight*	*1976*
8.	• Economic Geology of Australia and Papua New Guinea - 4 Industrial Minerals and Rocks	*Ed: C L Knight*	*1976*
9.	Field Geologists' Manual		
	1st Edition	*Ed: D A Berkman*	*1976*
	2nd Edition	*and W Ryall*	*1982*
	3rd Edition	*Ed: D A Berkman*	*1989*
	4th Edition	*Ed: D A Berkman*	*2001*
10	• Mining and Metallurgical Practices in Australasia (the Sir Maurice Mawby Memorial Volume)	*Ed: J T Woodcock*	*1980*
11.	• Victoria's Brown Coal - A Huge Fortune in Chancery (the Sir Willis Connolly Memorial Volume)	*Ed: J T Woodcock*	*1984*
12.	• Australasian Coal Mining Practice		
	1st Edition	*Ed: C H Martin*	*1986*
	2nd Edition	*Ed: C H Martin and A J Hargraves*	*1993*
13.	• Mineral Deposits of New Zealand	*Ed: Dr D Kear*	*1989*
14.	Geology of the Mineral Deposits of Australia and Papua New Guinea	*Ed: F E Hughes*	*1990*
15.	The Rocks Speak	*H King*	*1989*
16.	• Hidden Gold - The Central Norseman Story	*J D Campbell*	*1990*
17.	• Geological Aspects of the Discovery of Some Important Mineral Deposits in Australia	*K R Glasson and J H Rattigan*	*1990*
18.	• Down Under - Mineral Heritage in Australasia	*Sir Arvi Parbo*	*1992*
19.	Australasian Mining and Metallurgy (the Sir Maurice Mawby Memorial Volume)	*Ed: J T Woodcock and K Hamilton*	*1993*
20.	Cost Estimation Handbook for the Australian Mining Industry	*Ed: M Noakes and T Lanz*	*1993*
21.	History of Coal Mining in Australia (the Con Martin Memorial Volume)	*Ed: A J Hargraves, R J Kininmonth, C H Martin and S M C Saywell*	*1993*
22.	Geology of Australian and Papua New Guinean Mineral Deposits	*Ed: D Berkman and D Mackenzie*	*1998*
23.	Mineral Resource and Ore Reserve Estimation — The AusIMM Guide to Good Practice	*Ed: A C Edwards*	*2001*

Copies of all books currently in print can be obtained from

The Institute office - Tel (03) 9662 3166

Key: • Out of print

PUBLICATIONS OF THE AUSTRALASIAN INSTITUTE OF MINING AND METALLURGY

CONFERENCE, SYMPOSIUM AND MISCELLANEOUS

1972	1/72	S I	*	Project Evaluation and Management, Melbourne
	2/72		*	Annual Conference, Newcastle
1973	1/73	S2	*	Subsidence, Illawarra
	2/73	S3	*	Mine Filling, North West Queensland
	3/73	S4	*	Transportation, Sydney
	4/73	S8	*	Mine Fires, Southern Queensland
	5/73		*	Annual Conference, Western Australia
1974	1/74	S5	*	Support in Pillar Extraction, Illawarra
	2/74	S6	*	Recent Technical and Social Advances in the North Australian Minerals Industry, North West Queensland
	3/74	S7	*	Pellets and Granules, Newcastle and District
	4/74		*	Annual Conference, Southern and Central Queensland
1975	1/75	S9	*	People and the Mining Industry - The Future, Broken Hill
	2/75	S 10	*	Occupational Safety in Mines, Southern Queensland
	3/75	S 11	*	Australian Black Coal, Illawarra
	4/75		*	Annual Conference, South Australia
1976	1/76	S13	*	Landscaping and Land Use Planning as Related to Mining Operations, Adelaide
	2/76		*	Design and Construction of Tunnels and Shafts, Melbourne - 2nd Australian Tunnelling Conference
	3/76	S 14	*	Thick Seam Mining by Underground Methods, Central Queensland
	4/76	S 15	*	Sampling Practices in the Mineral Industries, Melbourne
	5/76		*	Annual Conference, Illawara
1977	1 /77	S 16	*	Apcom '77, Brisbane
	2/77	S 18	*	Coal Borehole Evaluation, Southern Queensland
	3/77	S 17	*	Underground Operators' Conference, Broken Hill
	4/77		*	Annual Conference, Hobart
1978	1/78	S 19	*	Mill Operators' Conference, North West Queensland
	2/78	S20	*	Rock Breaking Equipment and Techniques, Melbourne
	3/78		*	International Resource Management, Canberra
	4/78		*	Annual Conference, Townsville
1979	1/79	S21	*	Utilisation of Steelplant Slags, Illawarra
	2/79	S22	*	Estimation and Statement of Mineral Reserves, Sydney
	3/79		*	Annual Conference, Perth
1980	1/80		*	Annual Conference, New Zealand
	2/80	S23	*	Australia/Japan Extractive Metallurgy Symposium, Sydney
	3/80	S/24	*	Occurrence, Prediction and Control of Outbursts in Coal Mines, Southern Queensland
	4/80	S25	*	Management in the Mining Industry, Melbourne

Copies of all books currently in print can be obtained from The Institute office
Tel (03) 9662 3166 or Fax (03) 9662 3662

* = Out of print
The 'S' numbers in the third column refer to an older identifying number for Symposia, the numbers preceeding the 'S' number signify the new publication ordering number.

1981	1/81	S26	*	International Blast Furnace Hearth and Raceway Symposium, Newcastle
	2/81		*	Fourth Australian Tunnelling Conference
	3/81	S27	*	Ignitions, Explosions and Fires, Wollongong
	4/81		*	Annual Conference, Sydney
	5/81	S28	*	Strip Mining 45 Metres and Beyond, Central Queensland
1982	1/82	S29	*	Off Highway Truck Haulage Conference, Newman
	2/82	S30	*	Mill Operators' Conference, North West Queensland
	3/82	S31	*	Underground Operators' Conference, West Coast Tasmania
	4/82		*	Annual Conference, Melbourne
	5/82	S32	*	Carbon-In-Pulp Technology for the Extraction of Gold, Perth and Kalgoorlie, (Reprinted 1988)
	6/82	S33	*	Seam Gas Drainage with Particular Reference to the Working Seam, Wollongong
1983	1/83	S34	*	Computers in Mining, Southern Queensland
	2/83		*	Annual Conference, Broken Hill
	3/83	S35	*	Project Development Symposium, Sydney
	4/83	S37	*	Ventilation of Coal Mines, Wollongong
	5/83	S40	*	Principles of Mineral Flotation (The Wark Symposium), Adelaide
1984	1/84	S36	*	Metallurgy Symposium, Melbourne
	2/84	S38	*	Coal and Mineral Sizing, Wollongong
	3/84		*	Annual Conference, Darwin
	4/84	S39		Gold Mining, Metallurgy and Geology, Kalgoorlie
1985	1/85	S41	*	Smelting and Refining Operators' Symposium, North Queensland
	2/85	S42	*	Underground Operators' Conference, Kalgoorlie
	3/85		*	Annual Conference, Brisbane
	4/85	S43	*	Scientific and Technological Developments in Extractive Metallurgy (G K Williams Memorial Volume), Melbourne
1986	1/86		*	13th Congress The Council of Mining and Metallurgical Institutions, Singapore, 6 Volumes
	2/86	S44	*	Selective, Open Pit Gold Mining Seminar, Perth
	3/86	S45	*	Ground Movement and Control Related to Coal Mining, Wollongong
	4/86	S46	*	Australia: A World Source of Illmenite, Rutile, Monazite and Zircon Conference, Perth
	5/86	S47	*	Second Project Development Symposium, Sydney
	6/86	S48	*	Large Open Pit Mining Conference, Newman
	7/86	S49	*	Education and Research for the Mineral Industry for the Future, Melbourne
	8/86		*	The AusIMM 10 Year Index
1987	1/87		*	VI Australian Tunnelling Conference: Bore or Blast, Melbourne
	2/87	S50	*	Risk and Survival Seminar, Canberra
	3/87		*	Annual Conference, Newcastle: Coal Power '87
	4/87	S51	*	Research and Development in Extractive Metallurgy, Adelaide
	5/87		*	Leslie Bradford Golden Jubilee Oration
	6/87	S52	*	Mining and Environment: A Professional Approach, Brisbane
	7/87		*	Pacrim '87, Gold Coast, Queensland
	8/87	S53	*	Dense Medium Operators' Conference, Brisbane

Copies of all books currently in print can be obtained from The Institute office
Tel (03) 9662 3166 or Fax (03) 9662 3662

* = Out of print
The 'S' numbers in the third column refer to an older identifying number for Symposia, the numbers preceeding the 'S' number signify the new publication ordering number.

	9/87	S54	*	Equipment in the Minerals Industry: Exploration Mining and Processing Conference, Kalgoorlie
	10/87	S55	*	Resources and Reserves, Sydney
	11/87		*	South Australia's Mining Heritage
1988	1/88	S56	*	21st Century Higher Production Coal Mining Systems Symposium, Wollongong
	2/88		*	The Second International Conference on Prospecting in Arid Terrain, Perth
	3/88	S57	*	Third Mill Operators' Conference, Cobar
	4/88	S58	*	Underground Operators' Conference, Mount Isa
	5/88		*	Fourth International Mine Ventilation Congress, Brisbane, (Proceedings and Addendum volume)
	6/88		*	Annual Conference, Sydney: Minerals and Exploration at the Crossroads: The International Outreach
	7/88	S59	*	Second AusIMM Mineral Heritage Seminar, Sydney
	8/88	S60	*	Economics and Practice of Heap Leaching in Gold Mining Workshop, Cairns
	9/88		*	Third International Mine Water Congress, Melbourne
	10/88	S61	*	Explosives in Mining Workshop, Melbourne
1989	1/89		*	Mineralogy and Petrology, Sydney, February
	2/89		*	Second Large Open Pit Mining Conference, Latrobe Valley Vic
	3/89		*	NQ Gold '89 Conference, Townsville Qld
	4/89		*	Annual Conference, Perth-Kalgoorlie: Education, Training and Professional Development; Industrial Minerals; Project Development/Processing
	5/89		*	Mineral Fuel Alternatives and the Greenhouse Effect, July 1989
	6/89			Non-ferrous Smelting Symposium: 100 Years of Smelting and Refining Operations in Port Pirie, SA September 1989
	7/89		*	Dewatering Technology and Practice Conference, Brisbane October 1989
	89			MINVAL '89, Mining and Petroleum Valuation 1989, Sydney September 1989
1990	1 /90		*	Ore Reserve Estimates - The Impact on Miners and Financiers, Melbourne, March 1990
	2/90			Annual Conference, The Mineral Industry in New Zealand, Rotorua New Zealand, March 1990
	3/90			Pacific Rim Congress, Gold Coast Qld, May 1990
	4/90		*	Mining Industry Capital and Operating Cost Estimation Conference, Sydney, June 1990
	5/90		*	Third International Symposium on Rock Fragmentation by Blasting, Brisbane, August 1990
	6/90		*	Sir Edgeworth David Memorial Oration, May 1990
	7/90		*	Mine Geologists' Conference, Mount Isa, October 1990
1991	1/91		*	Fourth Mill Operators' Conference, Burnie Tas, March 1991
	2/91		*	World Gold '91, Cairns Qld, April 1991
	3/91			Mining Industry Optimisation Conference, Sydney, June 1991
	4/91		*	PNG Geology, Exploration and Mining Conference, Rabaul, June 1991
	5/91			Qld Coal Symposium, Brisbane, August 1991
	6/91		*	Reliability Production and Control in Coal Mines, Wollongong, September 1991
	7/91		*	Fifth AusIMM Extractive Metallurgy Conference, Perth, October 1991

Copies of all books currently in print can be obtained from The Institute office
Tel (03) 9662 3166 or Fax (03) 9662 3662

* = Out of print
The 'S' numbers in the third column refer to an older identifying number for Symposia, the numbers preceeding the 'S' number signify the new publication ordering number.

1992	1/92	*	Enviromine Australia, Sydney NSW, March 1992
	2/92		The AusIMM Annual Conference, 'The State-of-the-Art - A Product of 100 Years of Learning', Broken Hill NSW, May 1992
	3/92		'Energy, Economics and Environment' Gippsland Basin Symposium, Melbourne, June 1992
	4/92		Arnold Black Mineral Heritage Oration
	5/92		The Man from ASARCO: a life and times of Julius Kruttschnitt
	6/92		5th Underground Operators' Conference, Ballarat, July 1992
	7/92	*	11th International Conference on Ground Control in Mining, Wollongong, July 1992
	8/92	*	Third Large Open Pit Mining Conference, Mackay, August 1992
	9/92	*	Extractive Metallurgy of Gold and Base Metals Conference, Kalgoorlie, October 1992
	10/92	*	Sampling Practices in the Minerals Industry, Mount Isa, November 1992
	11/92	*	Rehabilitate Victoria, Latrobe Valley, November 1992
1993	1/93		Mining People - A Century
	2/93		The AusIMM Centenary Conference, Adelaide, March 1993
	3/93		XVIII International Mineral Processing Congress, Sydney, May 1993
	4/93	*	Narrow Vein Mining Seminar, Bendigo, June 1993
	5/93	*	International Mining Geology Conference, Kalgoorlie, July 1993
	6/93		VIII Australian Tunnelling Conference, Sydney, August 1993
	7/93	*	World Zinc '93 - International Symposium, Hobart, October 1993
1994	1/94		1994 AusIMM Student Conference, Brisbane, April 1994
	2/94	*	PNG Geology, Exploration and Mining Conference, Lae, PNG, June 1994
	3/94		No Two The Same by Bert Mason
	4/94		Sixth Extractive Metallurgy Conference, Brisbane July 1994
	5/94	*	1994 AusIMM Annual Conference, Darwin, August 1994
	6/94	*	4th Large Open Pit Mining Conference, Perth, September 1994
	7/94	*	Recent Trends in Heap Leaching, Bendigo, September 1994
	8/94	*	Maintenance in the Mining and Metallurgical Industries,Wollongong, October 1994
	9/94	*	Fifth Mill Operators' Conference, Roxby Downs, October 1994
	10/94		Mineral Valuation Methodologies 1994, Sydney, October 1994
	11/94		Victorian Mining Week Conference, Melbourne, October 1994
1995	1/95		1995 AusIMM Annual Conference, Newcastle, March 1995
	2/95		Sir Maurice Mawby Memorial Oration
	3/95		World's Best Practice in Mining and Processing Conference, Sydney, May 1995
	4/95		APCOM XXV 1995 Conference, Brisbane, July 1995
	5/95		Mineral Valuation Methodologies 1994, Sydney, October 1994 (revised)
	6/95	*	EXPLO 95 Conference, Brisbane, September 1995
	7/95		Underground Operators' Conference, Kalgoorlie, November 1995
	8/95	*	Young Professionals' Conference, Mt Isa, October 1995
	9/95	*	PACRIM '95 Congress, Auckland, New Zealand, November 1995
	10/95	*	Ethics, Liability and the Technical Expert, Sydney, December 1995

Copies of all books currently in print can be obtained from The Institute office
Tel (03) 9662 3166 or Fax (03) 9662 3662

* = Out of print
The 'S' numbers in the third column refer to an older identifying number for Symposia, the numbers preceeding the 'S' number signify the new publication ordering number.

1996	1/96	*	1996 AusIMM Annual Conference, Perth, March 1996
	1a/96	*	1996 AusIMM Annual Conference Supplementary Volume, Perth, March 1996
	2/96	*	Ethics, Liability and the Technical Expert, Sydney, March 1996
	3/96	*	Entrepreneurs and Partners, Sydney, July 1996
	4/96	*	Contract Operators' Conference, Kalgoorlie, October 1996
	5/96		Asia/Pacific Mining Communications Summit, Singapore, November 1996 - Withdrawn
	6/96	*	Nickel '96, Kalgoorlie, November 1996
1997	1/97		1997 AusIMM Annual Conference, Ballarat, March 1997
	2/97	*	World Gold '97 Conference, Singapore, September 1997
	3/97		Sixth Mill Operators' Conference, Madang, PNG, October 1997
	4/97		Gem 97, Madang, PNG, October 1997
	5/97	*	Contract Operators' Conference, Brisbane, Qld, October 1997
	6/97		Third International Mining Geology Conference, Launceston, Tas, November 1997
	7/97		Mindev 97 - The International Conference on Mine Project Development, Sydney, November 1997
	8/97		1997 AusIMM Travelling Technology Forum, Singleton, NSW, March 1997
1998	1/98	*	MINEFILL '98 - The Sixth International Symposium on Mining with Backfill, Brisbane, Qld, April 1998
	2/98	*	AusIMM'98 - The Mining Cycle, Mount Isa, Qld, April 1998
	3/98	*	Seventh Underground Operators' Conference, Townsville, Qld, June/July 1998
	4/98		Mine to Mill Conference, Brisbane, Qld, October 1998
	5/98		Third Regional APCOM - Computer Applications in the Minerals Industries International Symposium, Kalgoorlie, WA, December 1998
1999	1/99		10th Australian Tunnelling Conference, Melbourne, Vic, March 1999
	1a/99		10th Australian Tunnelling Conference Keynote Addresses and Asia–Pacific Forum, Melbourne, Vic, March 1999
	2/99		Students and Young Professionals Conference, Perth, WA, July 1999 (N/A)
	3/99		ICARISM '99 Conference, Perth, WA, September 1999
	4/99		PACRIM '99 Congress, Bali, October 1999
	5/99		EXPLO '99 Conference, Kalgoorlie, WA, November 1999
2000	1/2000		Southern Africa - Australia Mineral Sector Synergies Symposium, Canberra, ACT, March 2000
	2/2000		After 2000 - The Future of Mining, Sydney, NSW, April 2000
	3/2000		4th International Mining Geology Conference, Coolum, Qld, May 2000
	4/2000		Young Leaders 2000, Sydney, NSW, July 2000
	5/2000		MINPREX 2000, Melbourne, Vic, September 2000
	6/2000		Seventh Mill Operators' Conference, Kalgoorlie, WA, October 2000
	7/2000		MassMin 2000, Brisbane, Qld, October - November 2000
2001	1/2001		Strategic Mine Planning 2001, Perth, WA, March 2001
	2/2001		AusIMM Youth Congress 2001, Brisbane, Qld, May 2001
	3/2001		International Heavy Minerals Conference, Fremantle, WA, June 2001
	4/2001		EXPLO 2001, Hunter Valley, NSW, October 2001
	5/2001		Mineral Asset Valuation Issues 2001, Sydney, NSW, October 2001

Copies of all books currently in print can be obtained from The Institute office
Tel (03) 9662 3166 or Fax (03) 9662 3662

* Out of print

The 'S' numbers in the third column refer to an older identifying number for Symposia, the numbers preceeding the 'S' number signify the new publication ordering number.

2002	1/2002	Young Leaders 2002, Kalgoorlie, WA, March 2002
	2/2002	Metallurgical Plant Design and Operating Strategies, Sydney, NSW, April 2002
	3/2002	CMMI Congress, Cairns, Qld, May 2002
	4/2002	Green Processing Conference, Cairns, Qld, May 2002
	5/2002	Eighth Underground Operators' Conference, Townsville, Qld, July 2002
	6/2002	AusIMM 2002 Conference, 150 Years of Mining, Auckland, New Zealand, September 2002
	7/2002	Iron Ore Conference, Perth, WA, September 2002
	8/2002	Value Tracking Symposium, Brisbane, Qld, October 2002
2003	1/2003	Twelfth International Symposium on Mine Planning and Equipment Selection, Kalgoorlie, WA, April 2003
	2/2003	Young Leaders 2003, Brisbane, Qld, April 2003
	3/2003	Sixth International Conference Acid Rock Drainage, Cairns, Qld, July 2003
	4/2003	Eighth Mill Operators' Conference, Townsville, Qld, July 2003
	5/2003	Mining Risk Management Conference, Sydney, NSW, September 2003
	6/2003	Water in Mining 2003, Brisbane, Qld, October 2003
	7/2003	Fifth Large Open Pit Conference, Kalgoorlie, WA, November 2003
	8/2003	Fifth International Mining Geology Conference, Bendigo, Vic, November 2003
2004	1/2004	New Leaders 2004, Ballarat, Vic, April 2004
	2/2004	Second International Green Processing Conference, Fremantle, WA, May 2004
	3/2004	EXPLO 2004, Perth, WA, July 2004
	4/2004	Metallurgical Plant Design and Operating Strategies, Perth, WA, September 2004
	5/2004	PACRIM 2004 Congress, Adelaide, SA, September 2004
	6/2004	Bac-Min Conference, Bendigo, Vic, November 2004
	7/2004	Orebody Modelling and Strategic Mine Planning, Perth, WA, November 2004
2005	1/2005	Ninth Underground Operators' Conference, Perth, WA, March 2005
	2/2005	Coal2005 Conference, Brisbane, Qld, April 2005
	3/2005	New Leaders 2005, Brisbane, Qld, April 2005
	4/2005	Second World Conference on Sampling and Blending, Sunshine Coast, Qld, May 2005
	5/2005	Centenary of Flotation Symposium, Brisbane, Qld, June 2005
	6/2005	Eighth International Mine Ventilation Congress, Brisbane, Qld, July 2005
	7/2005	Hoist and Haul Conference, Perth, WA, September 2005
	8/2005	Iron Ore Conference, Fremantle, WA, September 2005
	9/2005	First Extractive Metallurgy Operators' Conference, Brisbane, Qld, November 2005

Copies of all books currently in print can be obtained from The Institute office
Tel (03) 9662 3166 or Fax (03) 9662 3662

* = Out of print
The 'S' numbers in the third column refer to an older identifying number for Symposia, the numbers preceeding the 'S' number signify the new publication ordering number.

SPECTRUM SERIES

1.	Making the Mount Isa Mine, 1923 - 1933	*Don Berkman*	*1996*
2.	History of Drilling	*Graham McGogggan*	*1996*
3.	The Cobar Mineral Field - A 1996 Perspective	*Warren Cook Andrew Ford Julian McDermott Peter Standish Craig Stegman and Therese Stegman*	*1996*
4.	Towards 2000 - Resource to Reserve Inputs Seminar - Melbourne, Vic		*1997*
5.	Towards 2000 - National Conference on Ironmaking Resources and Reserves Estimation, Perth, WA		*1997*
6.	Towards 2000 - The Resource Database Towards 2000 - Wollongong, NSW		*1997*
7.	Towards 2000 - Ore Reserves and Finance - Sydney, NSW		*1998*
8.	Towards 2000 - Assessment of Reserves in Low Rank Coals - Morwell, Vic		*1997*
9.	Towards 2000 - Ore Reserve Reconciliation Workshop - Darwin, NT		*1997*
10.	Towards 2000 - Gold and Nickel Ore Reserve Estimation Practice Seminar		*1998*
11.	Towards 2000 - Resource/Reserves Estimation Practice in the Central West New South Wales Mining Industry, Cobar, NSW		*1999*
12.	Field Guide for Geoscientists and Technicians		*2004*
13.	The Extractive Metallurgy of Zinc	*Roderick J Sinclair*	*2005*
14.	Orebody Modelling and Strategic Mine Planning – Uncertainty and Risk Management Models		*2005*

Copies of all books currently in print can be obtained from The Institute office
Tel (03) 9662 3166 or Fax (03) 9662 3662